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A Quantum Cure for Panphobia

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> "What reason have we to suppose that the hoped for revolution in our understanding of matter at the most fundamental level will involve ascribing essentially *mentalistic* properties to it?"
>
> *(Seager and Allen-Hermanson 2015: 31)*

> "Even the faint and blurry is phenomenology too much for the humble electron."
>
> *(McGinn 2006: 95)*

1. Introduction

When I was doing my PhD in the early 1990s, I was amused by Jerry Fodor writing about "epiphobia" – which he defined as the fear that one is turning into an epiphenomenalist (Fodor 1989: 59). The philosophers suffering from epiphobia were physicalists who did not want to deny the existence of intentional (understood as non-physical) states. The worry of epiphenomenalism was there because if one accepted the causal closure of the physical domain, there seemed to be no way that the intentional states *qua* intentional could be causally responsible for behavioural outcomes – which amounts to epiphenomenalism. But epiphobia is not the only worry a philosopher of mind can suffer from.

In his essay "Panpsychism" Thomas Nagel (1979) proposed that a set of reasonable assumptions, commonly held by philosophers, imply *panpsychism* – the view that the basic elements of matter ("physical ultimates") have mental properties. Nagel saw this option (which he took as a sign that something may not be quite right) as arising out of the assumptions that we ought to take conscious experience seriously, while denying psychophysical reductionism and radical emergence (for discussion, see Pylkkänen 1996). More recently Galen Strawson (2006) has with great force argued toward a similar conclusion, suggesting that the basic elements of matter even involve experience (Strawson 2006: 25). For him the idea arises as a result of assuming that everything concrete is physical; that everything physical is constituted out of physical ultimates, and that experience is part of concrete reality (2006: 25). Note especially that he considers "micropsychism" as the only reasonable option, not merely as something one arrives at via inference to the best explanation.

Those who find these arguments compelling may find themselves overcome by a worry, *panphobia*, which we can define, following Fodor, as the fear that one is turning into a panpsychist. Why should one be afraid of turning into a panpsychist? Strawson himself admits having felt abashed about arguing for panpsychism (2006: 186) and acknowledges that it is not easy to accept in the current intellectual climate (2006: 25). Nagel has remarked that "panpsychism has the faintly sickening odor of something put together in a metaphysical laboratory" (1986: 49), while Seager and Allen-Hermanson note that panpsychism has come to seem an implausible view, given our immense scientific knowledge of the physical world and the corresponding desire to explain everything in physical terms (2015: 1). Peter Simons summarizes more bluntly how many feel about this issue:

> "Panpsychism, at least in caricature, is one of the most immediately counterintuitive and off-putting of metaphysical positions. The idea of electrons making decisions about how to spin, nuclei harbouring intentions to split, or photons with existential Angst, makes idealism seem positively sane."

(Simons 2006: 146-7)

Colin McGinn provides a more sympathetic and yet critical characterization:

> "Panpsychism is surely one of the loveliest and most tempting views of reality ever devised; and it is not without its respectable motivations either. There are good arguments for it, and it would be wonderful if it were true – theoretically, aesthetically, humanly. Any reflective person must feel the pull of panpsychism once in a while. It's almost as good as pantheism! The trouble is that it's a complete myth, a comforting piece of utter balderdash."
>
> (McGinn 2006: 93)

If panpsychism is taken to mean that the elementary particles of physics (physical "ultimates") have proto-mental properties (Nagel 1986: 49), or even involve experience (Strawson 2006: 25), the doctrine seems very implausible. Nagel himself notes this:

> "What kind of properties could atoms have (even when they are part of a rock) that could qualify as proto-mental; and how could *any* properties of the chemical constituents of a brain combine to form a mental life?"

(Nagel 1986, p. 49)

Lycan underlines the lack of scientific evidence for panpsychism:

> ". . . there is nothing I can exhibit to show decisively that a muon or a quark is not a locus of experience. But neither is there any scientific evidence for panpsychism; there is no scientific reason, as opposed to philosophical argument, for believing it."

(Lycan 2006: 66)

He goes on to spell out the absurdity of the notion:

> ". . . if every ultimate particle has mental properties, what sorts of mental properties in particular do the particles have? It seems ludicrous to think that a photon has either sensory experiences or intentional states. (It does not even have mass.) How could it see, hear or smell anything? And if it has experiential properties, then presumably it also has rudimentary propositional attitudes. What would be the contents of its beliefs or desires? Perhaps it wishes it were a **u** quark."

(Lycan 2006: 70)

More technically, McGinn worries about the causal inefficacy of the micro-experiental that seems to be implicit in panpsychism (cf. epiphobia!):

> "Do the E [experiental] properties of elementary particles (or molecules or cells) contribute to their causal powers? If so, how come physics (and chemistry and biology) never have to take account of their contribution? . . . if they are agreed not to have any causal powers – and so are entirely epiphenomenal – how can they blossom into properties that do have such powers once they take up residence inside brains?"

(McGinn 2006: 94)

One apparent advantage of panpsychism is that it seems to solve the problem of how the experientality of an organism can emerge from its parts. McGinn however sees problems even here:

> "What kinds of E [experiental] properties do particles have? . . . This is a game without rules and without consequences. Is it really to be supposed that a particle can enjoy these kinds of experiences – say, feeling depressed at its monotonous life of orbiting a nucleus but occasionally cheered up by its experience of musical notes? [. . .] Even the faint and blurry is phenomenology too much for the humble electron. The problem is that we can solve the emergence problem only if we credit the ultimates with a rich enough phenomenology to form an adequate basis for a full-bodied human mind . . ."

(McGinn 2006: 95)

So, on the one hand we have excellent philosophers arguing that panpsychism is the only reasonable option, while equally excellent philosophers argue that the doctrine is just very implausible. Note in particular how the arguments against panpsychism appeal to our intuitions about elementary particles. It is assumed to be obvious that electrons cannot make decisions, nuclei cannot harbour intentions, photons cannot have sensory experiences, intentional states or existential Angst, and atoms cannot have proto-mental properties. Thus, anyone who feels the pull of panpsychism but also shares these common anti-panpsychist intuitions is likely to experience bouts of panphobia.

The story we will tell in this chapter does not go all the way to claim that elementary particles have all the properties that are ridiculed in the above quotes. However, we will propose that our best physics implies that elementary particles are far more complex than what is commonly supposed by contemporary materialist or physicalist philosophers of mind. Not only that, we will also show how some leading physicists have suggested that it is even reasonable to interpret some novel properties of elementary particles as protomental and that these protomental properties are causally efficacious. This, then, opens up the possibility for a scientific argument for panpsychism – or at least panprotopsychism, the weaker doctrine according to which the ultimates have proto-mental properties, rather than mental properties in a full sense.

Epiphobia and panphobia lie at the opposite ends of a spectrum in philosophy of mind. An epiphobic worries that one's mind-matter theory gives too weak a role for mind, while a panphobic worries that it gives too strong a role. In this chapter we will explore whether a cure for *both* epiphobia *and* panphobia might be found in quantum theory.

2. The Ontological Interpretation of Quantum Theory

Quantum phenomena exhibit a curious combination of wave and particle behavior. For example, in the famous two-slit experiment, electrons arrive one by one at the detecting screen at localized points, suggesting that they are particles. Yet as we keep on watching, the individual spots gradually build up an interference pattern typical of wave behavior, suggesting that each individual electron ALSO has wave properties. The usual interpretation of quantum theory describes the electron with a wave function. In the minimalist (Bohr's) version, the wave function only allows us to calculate probabilities for finding the electron (as a localized particle) at a given location. In other words, the wave function is seen as a part of a mathematical algorithm and is not given an ontological interpretation. However, following von Neumann, many physicists assumed that the wave function provides a complete description of an individual quantum object. This gives rise to the many infamous puzzles of quantum theory, such as the claim that a single electron is in two (or more) places at once; that a cat is alive and dead at the same time; that the world at the macroscopic level is constantly branching into copies ("many worlds"); and that to solve such problems we must assume an *ad hoc* collapse of the wave function, or assume that the non-physical consciousness of the observer plays an active role (for some of the problems with von Neumann's approach, see Bohm and Hiley 1993, ch 2). Thus, it seems that quantum theory forces us to choose between Bohrian instrumentalism/antirealism or some very counterintuitive realist interpretation. (For a brief introduction to quantum theory, see Polkinghorne 2002; Pylkkänen 2018; see also Lewis 2016; for Bohr's views see Plotnitsky 2010)

An apparently more sober realist version of quantum theory was discovered by Louis de Broglie in 1927 and independently rediscovered and further developed by David Bohm in 1952 and in subsequent research. In this theory the electron is seen as a particle AND a wave. In the two-slit experiment the particle goes through one of the slits. The wave goes through both slits, interferes and guides the particle in such a way that an interference pattern is gradually formed, spot by spot, as many electrons pass through the slit system (thus the theory has also been called the pilot wave theory). It thus seems that we can have a realist or ontological interpretation of the quantum theory, without the usual puzzles, such as Schrödinger's cat, many worlds, collapse of the wave function, or the consciousness of the observer producing physical reality (see Bacciagaluppi and Valentini 2009; Bohm 1952a and 1952b; Bohm and Hiley 1987, 1993; Bricmont 2016; for latest developments, see Walleczek et al. (eds.) 2018; Pylkkänen et al. 2016)).

However, the Bohm theory, too, has exotic features. For one thing it implies a non-local interaction between particles at a quantum level, creating a tension with relativity. Note however that this non-locality is characteristic of quantum theory in general and consistent with the experimental results (see Walleczek and Grössing 2016). Also, the wave function for a many-body system lives in a multidimensional configuration space, making it difficult to assume that it describes an ordinary physical field in a 3-dimensional space (see Ney and Albert (eds.) 2013). To alleviate this problem (and for other reasons) Bohm and Hiley (1987, 1993) proposed the radically new notion that the wave function describes not an ordinary physical field, but rather a field of information, which literally in-forms the energy of the particle. Bohm (1990) further proposed that such "active information" can be seen as a primitive mind-like quality of elementary particles. Here, then, opens up the possibility for scientific (rather than merely philosophical) support for panprotopsychism. Let us thus examine the Bohm theory in more detail.

While it is common in the usual interpretation of quantum theory to say that a quantum object (such as an electron) is a particle OR a wave (depending on the context), the Bohm theory, as we already mentioned, says less ambiguously that an electron is always a particle AND a wave. More precisely, it assumes that every particle has a well-defined position and momentum and is accompanied by a new type of field, described by the wave function ψ which satisfies the Schrödinger equation. The field affects the particle via a new potential, *the quantum potential Q* (eq. 1):

$$Q = -\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R}$$

This suggests a model of, say, an electron as a particle which moves along a trajectory and which is influenced not just by classical potentials but also by the new quantum potential. The quantum potential accounts for all (non-relativistic) quantum behavior, and in situations where the quantum potential is negligible, classical physics provides a good approximation. From the perspective of the Bohm theory we can call the physical world “an overall quantum world”. Within this world there is a classical sub-world – that is, a domain where the quantum potential has a negligible effect (e.g. due to temperature), and Newton’s laws provide a good approximate description for how a macroscopic object (e.g. a chair) behaves. But in circumstances where the quantum potential is not negligible (e.g. in quantum experiments), the behavior of particles can be radically non-classical,

Figures 1 and 2 provide well-known visualizations for the two-slit experiment (from Philippidis et al. 1979). In Figure 1 we are looking toward a partition with two slits in it. The electrons are moving toward us (one by one) and as they go through one of slits they encounter a quantum potential. One can think of a potential as a bit analogous to a mountain, so that the quan- tum potential will, for example, keep the electrons away from areas where it has a high value.

The electrons have their source in a hot filament, which means that there is a random statistical variation in their initial positions. This means that each particle typically enters the slit system in a different place. Figure 2 shows possible trajectories than an electron can take after it goes through

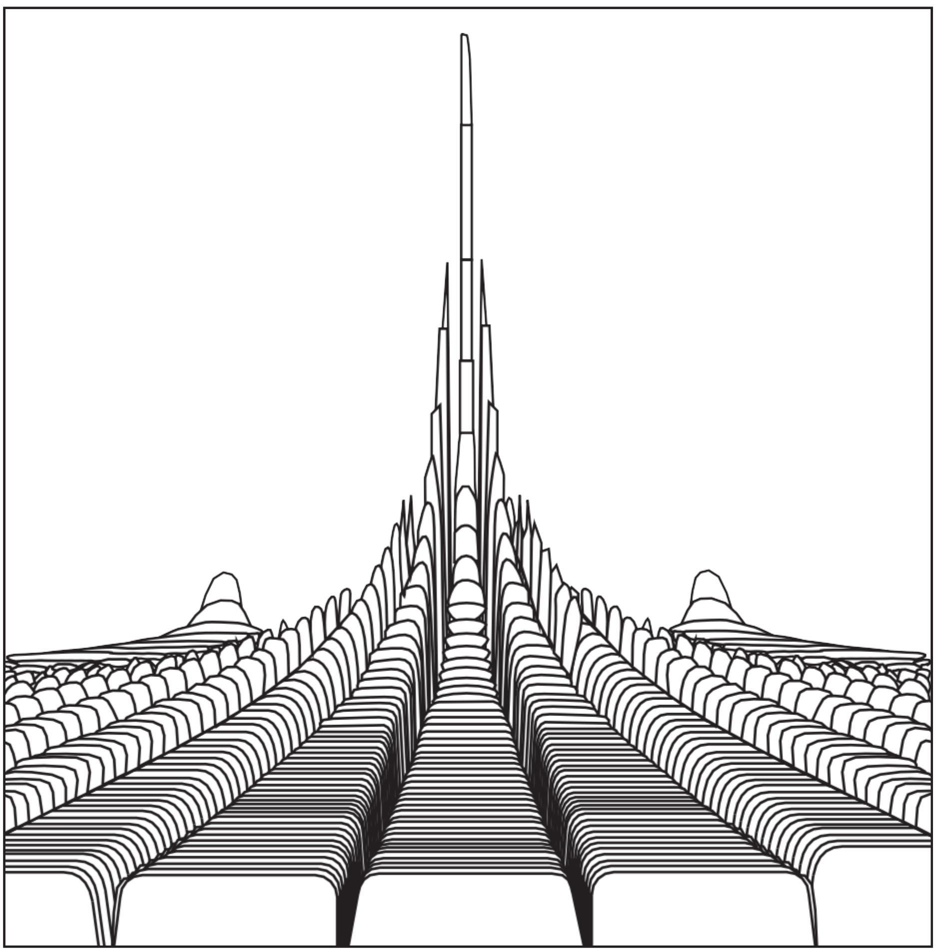

Figure 1 Quantum potential for two Gaussian slits

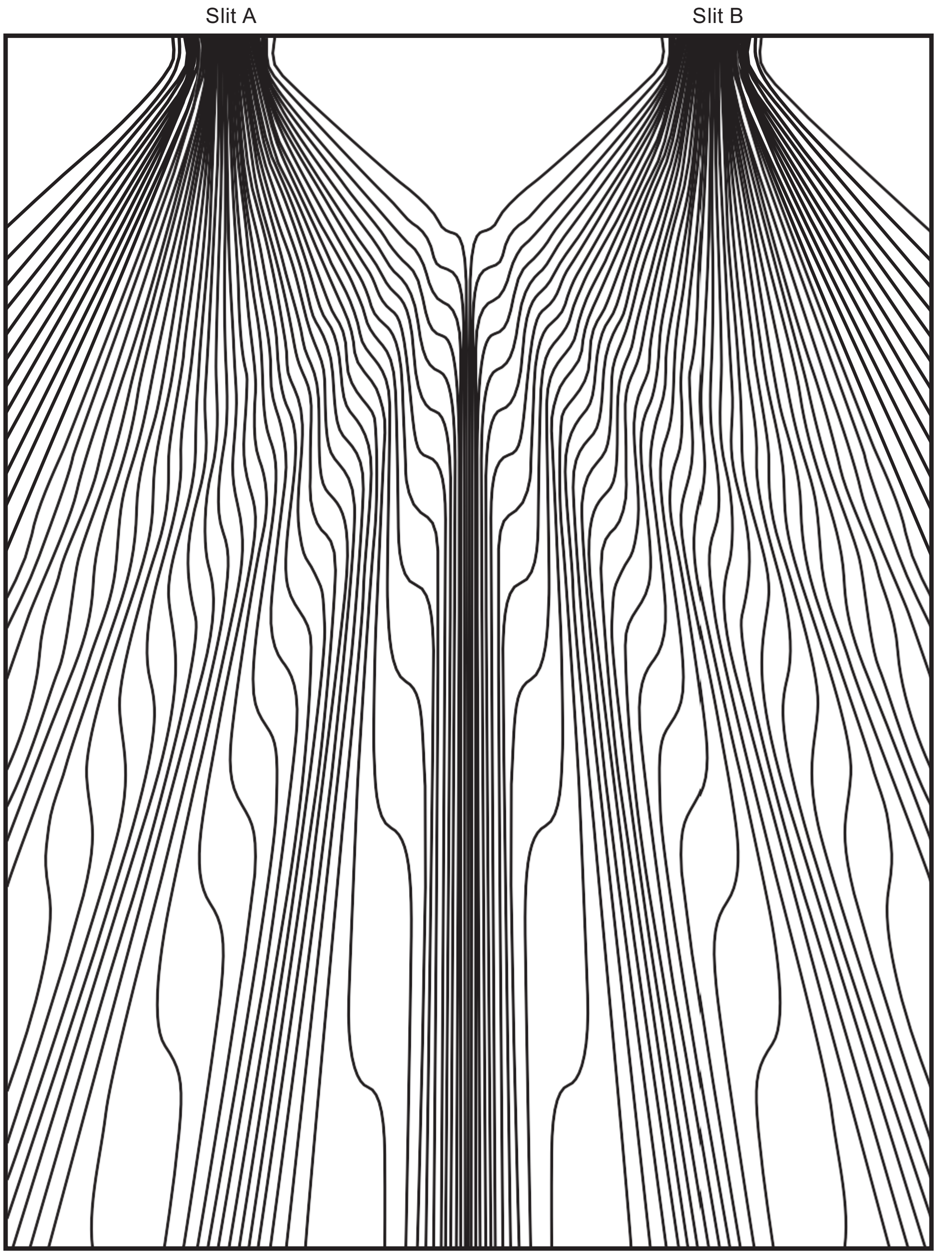

Figure 2 Trajectories for two Gaussian slits

the slits. Which trajectory it takes depends, of course, on which place it happens to enter the slit system.

Note that the trajectories should be seen as a *hypothesis* about what may be going on in the two-slit experiment. Because of the uncertainty principle it is not possible to measure the initial conditions (position and momentum) of a particle simultaneously with an accuracy that would enable us to predict which trajectory a given individual electron will follow (however, measurements of so-called weak values allow us to calculate average trajectories, see Flack et al. 2018).

3. The Interpretation of the Quantum Field as Active Information

In the 1970s Bohm and Hiley (1975) began to re-examine the de Broglie–Bohm theory, partly as a result of the interest their research students were showing in this approach, as well as the new attention to the question of non-locality due to John Bell's work (see Bell 1987). They considered the mathematical expression of the quantum potential, which describes the way the quantum wave field affects the particle (eq. 1)

$$Q = -\frac{\hbar^2}{2m}\frac{\nabla^2 R}{R}$$

Here h-bar is Planck's constant divided by 2π, m is the mass of the particle, R is the amplitude of the quantum wave and ∇^2 is a differential operator which takes the second spatial derivative of R. The term $\nabla^2 R$ reflects how R changes, i.e., the shape or form of the quantum wave. In classical physics (e.g. with the classical electromagnetic field), a potential depends on the amplitude of the field (somewhat like the size of a water wave determines the effect the wave has on a floating object). However, Bohm realized that the quantum potential, and thus the effect of the quantum field upon the particle, depends *only* on the form or shape of the field, not on its size or amplitude R. This is so because R appears both in the nominator and the denumerator in the right hand side of equation 1, and so can be multiplied by an arbitrary constant without changing the quantum potential; a wave of small amplitude thus has the same effect as a wave of large amplitude, as long as the waves have the same form. Bohm was thereby led to suggest that the quantum field is not pushing and pulling the particle mechanically, but rather the quantum field literally puts form into or "in-forms" the particle to behave in a certain way. The idea is that the electron is moving under its own energy that is being in-formed by the quantum field.

Bohm proposed that this is an instance of a general feature of *active information* that we see operating at many levels of nature (for discussion, see Seager 2018). The basic idea of active information is that a low-energy form enters a greater energy and as a result the form of the greater energy becomes the same as that of the smaller energy. If you consider a ship on autopilot guided by radar waves, the waves are not pushing and pulling the ship. Rather, the form of the waves is taken up by the autopilot device and is used to direct the ship. Analogously the quantum field contains information about the environment of the particle (e.g. slits) and this information, along with the classical forces, then determines the movement of the particle. Note, however, that there are important differences between the ship analogy and the electron. It is important to emphasize that with the electron we encounter holistic active information (with non-locality and irreducible wholeness), as opposed to the more (classical) mechanical active information we encounter in the ship analogy (Pylkkänen 1992: 95–6; Dickson 1996: 234).

Bohm also realized that the idea that the essential nature of the quantum field is that it is information, rather than an ordinary physical field, enables one to make sense of the notorious multidimensionality of the many-body quantum field. With information, multidimensionality is a natural concept in the sense that information can be organized into as many dimensions as may be needed. As we will see later, the many-body quantum field can be seen as a *common pool of information* for the two particles.

One important potential criticism of the active information approach has to do with the notion of information that is presupposed. Is it really justified to use the term "information" to describe the sorts of processes connected to the quantum field? One can examine this question in the light of recent developments in the philosophy of information (e.g. Floridi 2015). Floridi distinguishes between semantic and environmental information. Semantic information involves factual semantic contents (i.e. information as meaningful data that represents facts correctly or incorrectly). Environmental information sees information as mere correlation, e.g. the way tree rings carry information about age. Semantic information can be further distinguished into factual and instructional information. The quantum active information is *about* something (the environment, slits, etc.), it is *for* the particle and it helps to *bring about* something (a certain movement of the particle). This suggests that it is not merely correlational but is also (proto)semantic and has both factual and instructional aspects (see Pylkkänen 1992: 96–8). Also, Maleeh and Amani (2012) have usefully considered active information in relation to Roederer's (2005) notion of pragmatic information, suggesting that only biological systems are capable of "genuine" information processing. I think one can argue that Bohmian quantum information potential involves genuine information processing (indeed, the most fundamental kind of genuine information processing science has thus far discovered).

While the notion of active information in quantum theory has not been widely accepted (for criticism see Riggs 2008), some leading thinkers do take it seriously (e.g. Smith 2003). Also, an interesting adaptation of the active information scheme to neuroscience has been proposed by Thomas Filk (2012). In the field of the social sciences, Andrei Khrennikov (2004) has made imaginative use of the proposal and the Bohm theory – as an analogical model – has also been applied to financial processes by Olga Choustova (2007) and Emmanuel Haven (2005). For other ways of using the mathematical and conceptual tools of quantum theory to model cognition, see Wang et al. (2013). Of course, the notion of "quantum information" has been extensively discussed in recent years (e.g. Bouwmeester et al. 2000). The advantages of the concept of active information over quantum information are explored in Maroney (2002) and Maroney and Hiley (1999). Note finally that the Bohm theory can be presented in a more minimalist way without giving the quantum potential (and active information) a key role (see Goldstein 2013). Bohm, however, felt that at least something like the notion of active information is needed if we want to give an intelligible ontological interpretation of quantum theory (Bohm and Hiley 1993: 60; see also Holland 1995: 90-1).

4. Is information a Mind-Like Quality?

So let us assume, for the sake of the argument, that it is a reasonable hypothesis that the quantum field encodes information. What reasons do we have to think that such information is a "primitive mind-like quality", as Bohm suggested? The idea that cognition is information processing has, of course, been a central notion in cognitive psychology and cognitive science (Velmans 2009: 64–79). Note also that some other researchers in philosophy of mind and consciousness studies have made use of the concept of information in their theories of mind and consciousness. For example, Dretske (1981) and Barwise and Seligman (1997) have explored the possibility that information in the sense of factual semantic contents can be grounded in environmental information. For Dretske this was an important part of his attempts to give a naturalistic account of sensory experiences, qualia and consciousness. During recent years the notion of information has been used to explain consciousness most notably by David Chalmers (1996), as well as by Giulio Tononi and his co-workers (Tononi and Koch 2014; Oizumi et al. 2014); see also Velmans (1991a, 1991b). The relation of Bohm's active information to Chalmers's views has been discussed in Pylkkänen (2007: 244–6), while its relation to Tononi's views is discussed in Pylkkänen (2016). While Bohm's notion of information differs from the notions of information mentioned above, there are some relevant similarities. For example, both Bohm's and Tononi's notions of information differ from Shannon information in that they refer to the literal meaning of information as "in-forming", albeit in different ways.

The preceding indicates that the idea that information is a mind-like quality is one of the key options in contemporary discussions about the nature of mental states. In the light of this, Bohm's proposal that quantum theoretical active information is a primitive mind-like quality of elementary particles seems not too unreasonable. The proposal implies that electrons have "proto-cognition" (because of the information aspect) and "proto-will" (because the information is fundamentally active) (cf. Wendt 2015: 139). Whether it also implies that electrons have proto-phenomenal properties is a more tricky question. But one could claim that the electron is in some sense "perceiving" or monitoring its environment via its information field, and that such "perceiving" involves proto-phenomenality.

5. Active Information and the Relation of Mind and Matter

Bohm also thought that the idea of active information at the quantum level opened up a way to tackle a perennial problem in philosophy, namely that of the relationship between mind and matter (1989, 1990). First of all, he suggested that mental states involve a hierarchy of levels of active information. We do not merely think about objects in the external world, but we can also become aware of our thinking. He suggested that such meta-level awareness typically gives rise to a higher level of information. This higher level gathers information about the lower level. But because its essential nature is active information, it does not merely make a passive representation of the lower level. Rather, the higher level also acts to organize the lower level, a bit analogously to the way the active information in the pilot wave acts to organize the movement of the particle. And of course, we can become aware of this higher level of information from a yet higher level, and so on.

How then does mind, understood as a hierarchy of levels of active information, connect with matter in the Bohmian scheme? First of all, he suggested that it is natural to extend the quantum ontology. So just as there is a pilot wave that guides the particle, there can be a super-pilot wave that can organize the first-order pilot wave, and so on. He claimed that such an extension is "natural" from the mathematical point of view (Bohm and Hiley (1993: 378–81, 385) discuss such extensions in the context of quantum field theory). Now it seems that we have two hierarchies, one for mind and another for matter. Bohm's next step was to postulate that these are the same hierarchy, so that there is only one hierarchy. This then allows, at least in principle, for a new way of understanding how mind and body can affect each other. The meaning of information at a given level in the mind can act downwards, all the way to the active information in the pilot waves of particles in, say, the synapses or neural microtubules, and this influence can then be amplified to signals in motor cortex, leading to a physical movement of the body (see Hiley and Pylkkänen 2005). In a reverse process, perception can carry information about the external world and the inner state of the body to higher levels, where the meaning of the information is apprehended, and can unfold again to organize the more manifest levels. (For criticisms see Kieseppä (1997a, 1997b), Chrisley (1997); for replies, see Hiley and Pylkkänen (1997, 2001) and Pylkkänen (1992: 96)). Bohm's discussion fits well with the idea of the mind-brain as a self-organizing system. Jenann Ismael (2016) has emphasized that the human mind also essentially includes a self-governing system which is capable of deliberative reasoning and self-conscious thought. In the Bohmian scheme one can say that even conscious reflection in thought happens according to the total meaning that prevails in a situation (see Bohm 1990: 282). This weakens the distinction between self-organizing and self-governing systems.

6. Quantum Ballet: The Priority of the Whole

As has already been hinted previously, the ontological interpretation also brings into focus the "undivided wholeness" characteristic of the quantum world, implying a monistic metaphysics (cf. Schaffer 2010). This wholeness can be seen already when considering a single particle, for because the quantum potential only depends upon the form of the field, it does not necessarily fall off with distance even if the intensity of the field becomes weak as the field spreads out. Thus even distant features (e.g. slits) of the environment of the particle can have a strong effect upon the particle, implying that there can be a strong context-dependence in the behaviour of the particle. In the two-body system there is wholeness also in the sense that the quantum potential depends on the position of both particles in a way that does not necessarily fall off with the distance, implying the possibility of a non-local interaction between the two particles. And we can generalize this to the N-body system where the behaviour of each particle may depend non-locally on all the others, regardless of how far away they may be (Bohm and Hiley 1987: 330).

Nonlocality is an important new feature of the quantum theory, but Bohm emphasized that there is yet another feature that is even more radical, namely that the quantum potential *Q* depends on the quantum state of the whole system in a way that cannot be defined simply as a pre-assigned interaction between all the particles. This underlines the priority of the whole that is typical of quantum systems (cf. Schaffer 2010). For example, in the Hydrogen atom the interaction of the electron and the proton depends on the quantum state of the whole system in a way that cannot be expressed in terms of the relationships of the particles alone. In this sense the whole is prior to its parts in the quantum domain (see Bohm and Hiley 1987: 331-2; see also Holland 1995: 281-2).

In Bohmian terms the quantum state can be seen as a *common pool of information* that is guiding the particles in the system. Note also that the quantum state is evolving in time according to Schrödinger's equation, so it is a dynamic whole that is guiding the particles. Bohm thus thought that quantum theory was primarily about dynamical wholeness that is not reducible to the interactions between individuals. As Max Jammer has pointed out, this means that the individuals are not "constitutive" to the whole but rather depend on the state of the whole (1988: 696).

However, the physical world we find in everyday experience can be approximately described in terms of classical physics, characterized by relatively independent and separable objects. How do we get from quantum wholeness to classical separability? The answer is that in certain circumstances the wave function (i.e. the quantum field) of a system *factorizes* into two parts, and the corresponding subsystems will then behave independently. These factorized parts of the wave functions represent independent pools of information. The subsystems will cease to be guided by a common pool of information and will instead respond to independent pools.

An example that illustrates the preceding is provided by superconductivity where electrons at low temperatures are able to move without resistance in a wire. In terms of the Bohm theory this happens because the electrons are guided by a common wave function (or common pool of information) to move in such a way that they do not scatter from obstacles but rather go around them in a coordinated way. This is like a "ballet dance" where the wave function is the score and the particles are the dancers. At higher temperatures the property of superconductivity disappears. This is because the wave function factorizes into independent pools of information, and the particles behave independently and scatter from obstacles. The particles are no longer like ballet dancers but are now like an unorganized crowd of people who are acting independently and get in each other's way (1993: 71). The key point is that the quantum potential arising under certain conditions can organize the activity of an entire set of particles in a way that depends directly on the state of the whole. Bohm and Hiley think it is plausible that such an organization can be carried to higher and higher levels and eventually may become relevant to living beings. Indeed, given the recent advances in quantum biology (Ball 2011, Marais et al. 2018)), it is tempting to speculate that the quantum potential (or some higher-order quantum-like "biological potential") plays a relevant role in determining whether a system is "living" or "non-living". The idea is that when the quantum potential within a biological system has a non-negligible effect, it provides the organic unity characteristic of a living system. Death, on the other hand, would correspond to a situation when the wave function factorizes and the system loses its organic unity (cf. Pylkkänen 1992: 55).

Mental states, too, can be seen as involving common pools of information which guide and coordinate spatially distinct neural activities. Taken as a literal quantum model of the brain, a Bohmian common pool of quantum information in the brain would imply that there can be non-local correlations between particles in spatially separate brain areas. This, of course, is a speculative idea, but recent advances in quantum brain theory (see Hameroff and Penrose 2014) make such a radical idea at least conceivable.

Note also that the idea of a common pool of information is interestingly similar to Baars's (2007) idea of a global workspace in consciousness studies. If we assume that consciousness would correspond to a situation where a common pool of mental information is having a global effect on distinct neural modules, then we could say that the transition from conscious to non-conscious state corresponds to some kind of factorization of such a conscious common pool of information to non-conscious independent pools. However, as Rosenthal (2009) has pointed out, while consciousness is sometimes connected with the global effects of a workspace, there also seem to be situations where there are conscious states without such global effects (e.g. conscious peripheral perceptions), and non-conscious states with global effects (e.g. non-conscious thoughts as steps in problem solving). Thus it does not seem reasonable to identify consciousness with the operation of a global workspace or common pools of information in connection with neural processes, even though these may often be correlated (for discussion, see Velmans 2009: 274-81). We will return to the issue of consciousness later.

7. The Ontological Interpretation and the History of Panpsychism

The ontological interpretation resonates with many panpsychist approaches in the history of philosophy. We saw previously that this interpretation involves a top-down approach in the sense that the basic law (which involves active information) refers to the whole universe, and that through factorization we get relatively independent sub-wholes, each guided by their pools of information. We can even imagine a wide range of situations where the quantum potential (and thus the influence of active information) upon an elementary particle becomes negligibly small, in which case classical physics provides a good approximate description of the behaviour of the particle (and aggregates of such particles, such as tables and chairs). In this sense any Bohmian panpsychism is top down – a mind-like quality (active information) is an essential part of the basic law that applies to the universe as a whole, but it is not necessary to always attribute mind-like qualities to the ultimate constituents of matter. The Bohmian scheme thus allows us to make a distinction between things with mind-like qualities and things lacking mind-like qualities. At the level of fundamental physics, particles for which the quantum potential is negligible lack (for all practical purposes) mind-like qualities, while particles for which the quantum potential is non-negligible have mind-like qualities. Similarly, at the macroscopic level we can make a distinction between systems where some kind of active information is having a non-negligible effect (and the system [e.g., a c~~hair]~~ has mind-like qualities) and systems where such effect is negligibly small (and the system has no mind-like qualities). This view is reminiscent of Fechner's endorsement of a "world-mind" of which everything is a part. Fechner's view did not require that every thing in the world be itself enminded (Seager and Allen-Hermanson 2015: 5).

Bohm's way of thinking fits particularly well with Leibniz's panpsychism. Leibniz's idea that each monad carries within it complete information about the entire universe is captured by Bohm's general notion of the implicate order, according to which each part of the universe enfolds information about the universe as a whole in a holographic manner (Bohm 1980; see also Pylkkänen 2007, Seager 2013). For Leibniz space and time emerge from sets of relations amongst the monads (Seager and Allen-Hermanson 2015 11). This again fits with the idea that the implicate order describes a kind of pre-space out of which the ordinary 3-dimensional space unfolds (Bohm and Hiley 1984). Seager and Allen-Hermanson note that the only model Leibniz found adequate to describe his monads was one of perception and spontaneous activity. This is analogous with the Bohmian electron, if we assume there is a sense in which the electron "perceives" its environment via the quantum field, and that the flexibility allowed by the hierarchy of quantum fields of information makes possible a kind of spontaneity on the activity of the electron A further similarity between the Leibnizian and

Bohmian panpsychist schemes is that both can make a distinction between things that have mental attributes from those who do not. Leibniz held that there is a difference between a "mere aggregate" (e.g. a heap of sand) and the "organic unity" of an organism. In Bohmian terms a "mere aggregate" corresponds to a situation where the wave function of a system of particles has factorized in such a way that each particle is guided only by its own pool of information (and when the quantum potential of a particle has a negligible effect, so that classical laws prevail), while "organic unity" corresponds to a situation where particles are guided by a common pool of information, with a non-negligible quantum potential.

8. An analogical argument for panpsychism based on the ontological interpretation

Seager and Allen-Hermanson (2015: 26) characterize a typical argument from analogy for panpsychism as follows: "if we look closely, with an open mind, we see that even the simplest forms of matter actually exhibit behavior which is akin to that we associate with mentality in animals and human beings." They note that one fairly promising analogy is provided by the indeterminism of quantum mechanics, and draw attention to how Whitehead wanted to see this indeterminacy "... as an expression not of blind chance but spontaneous *freedom* in response to a kind of *informational inclination* rather than mechanical causation." This general idea fits quite well with the way Bohm made use of notions such as active information and "generative order" to characterize freedom and causation (Bohm and Peat 2000). While it is usually assumed that quantum indeterminacy is pure randomness and as such remote from deliberation, decision and indecision (Seager and Allen-Hermanson 2015: 27), reasonable extensions of quantum theory (e.g. Penrose 1994; Bohm and Hiley 1993: 378-381) can go towards capturing the kind of interplay of spontaneity, contingency and determination that is characteristic of human deliberation and decision.

Seager and Allen-Hermanson think that a more promising quantum theory related analogical argument for panpsychism has to do with the relation between consciousness and information. The idea is that an important function of consciousness is to integrate information and to monitor external and internal states. This idea can be developed into a view that monitoring and integrated information actually make for consciousness (Lycan 1996: 40, quoted in Seager and Allen-Hermanson 2015: 27). Seager and Allen-Hermanson note: ". . . it follows from this view that *if* information monitoring is a fundamental and pervasive feature of the world at even the most basic levels, then consciousness too should appear at those levels" (2015: 27-8). There is a sense in which quantum theoretical active information involves information monitoring, so in case the ontological interpretation is correct, philosophers who emphasize the link between monitoring and consciousness, such as Lycan, may be closer to panpsychism than they realize (cf. Lycan's remarks about the lack of scientific evidence for panpsychism that we cited in the Introduction). Also, Seager and Allen-Hermanson suggest that already according to the usual interpretation of quantum theory, experiments on entangled photons imply that two entangled photons are effectively monitoring each other's state of polarization (2015: 28). Thus, regardless of whether we are using Bohm and Hiley's ontological interpretation, or the usual interpretation of quantum theory, it can be argued that quantum theory implies that some kind of superluminal informational monitoring is taking place at a fundamental level of the physical world (it is likely, however, that this does not involve superluminal signaling or communication, see Walleczek and Grössing (2016)).

If one accepts that monitoring and integrated information make for consciousness then, if Seager and Allen-Hermanson are correct, the quantum theory implies that there is at least elementary consciousness associated with quantum phenomena. However, as we have seen, Bohm for one thought that it is obvious that elementary particles are not conscious. We will return to this issue later.

9. The Combination Problem

Bohm and Hiley's interpretation provides a novel way of approaching the combination problem of panpsychism, i.e. the problem of explaining how the (primitive) consciousness of the elements of a system could possibly combine into the full consciousness of the system. Nagel, for example, worries about not only what the proto-mental properties of atoms could possibly be but also about how they could "combine to form the mental life that we are all familiar" and "how could any properties of the chemical constituents of a brain combine to form a mental life?" (1986: 49–50).

We have seen already that quantum theory challenges some key assumptions on the basis of which the combination problem has traditionally been formulated in the first place. For while the problem typically presupposes in a bottom-up fashion that the properties of the whole have to be explained in terms of the properties of the parts, quantum theory strongly points to a monistic ontology, in the sense that the whole is prior to its parts (cf. Schaffer 2010). This does not deny the existence of the parts, nor does it deny that some aspects of the whole can be conveniently understood in terms of the properties of the parts. But, as we have seen earlier, there are quite generally instances in quantum theory (brought out especially clearly by the ontological interpretation) where the whole is prior to parts in the sense that the behaviour of individual particles cannot be understood in terms of their spatial relationships only. So we do not explain the behaviour of the whole in a bottom-up way in terms of the behaviour of the parts, but rather explain the behaviour of the parts in a top-down way partly in terms of the properties of the whole.

We also saw that in terms of the ontological interpretation, the particles in a many-body quantum system are guided by a "common pool" of information that cannot be reduced to the "private pools" of individual particles. On the contrary, the whole is prior to the parts in the sense that these private pools arise from the common pool in certain circumstances through factorization. Thus quantum reality seems to provide a powerful holistic principle of combination, which in the ontological interpretation can be understood in terms of a quantum potential, a new kind of non-local, holistic organizing factor. Regarding the combination problem, the ontological interpretation provides one way of understanding, at least as an analogy, how a subsystem (such as a human being) can have properties (e.g. consciousness) that need not be accounted for entirely by the properties of the parts of the subsystem (e.g. elementary consciousness of the parts). Thus, while the ontological interpretation has a panpsychist flavour in postulating that elementary particles have mind-like qualities (when the quantum potential for a particle is non-negligible), its emphasis on the priority of the whole goes against the spirit of the bottom-up way of explaining consciousness characteristic of traditional panpsychism. This can be seen as a deflationary approach to the combination problem (Ilpo Hirvonen, private communication).

10. Active Information and Conscious Experience

The preceding gives rise to the question of what the origin of conscious experience is in the Bohmian scheme. We have noted that in this scheme the whole is primary, in the sense that active information associated with an elementary particle derives from a common pool of information, ultimately that of the universe as a whole. However, if we think of the quantum field of the universe in the light of the ontological interpretation, there seems to be no reason to think that the active information encoded in this vastly multidimensional quantum field is conscious. Indeed, while Bohm saw nature as a dynamic process where information and meaning play a key dynamic role, he assumed that "99.99 per cent "of our meanings are not conscious (see Weber 1987: 439). But how can one then address the problem of consciousness in this scheme? In other words, why is there sometimes conscious experience associated with the activity of information? Why doesn't all the activity of information in humans proceed "in the dark", as it seems to do in physical and biological processes in general?

Given that Bohm's mind-matter scheme has a hierarchical structure, one natural possibility to explore is whether some version of a higher-order theory of consciousness could be applied here. Alternatively one could try to apply Tononi's integrated information theory of consciousness (Oizumi et al. 2014) to active information, or consider the relationship of the active information scheme (with its emphasis on common pools of information) to Baars's (2007) global workspace theory of consciousness. Or perhaps a suitable combination and modification of these theories would do the job of accounting for consciousness in the active information scheme? One thing to consider here is that Tononi's theory has been subject to severe criticisms by Scott Aaronson, who argues that according to Tononi's theory a simple Reed-Solomon decoding circuit would, if scaled to a large enough size, bring into being a consciousness vastly exceeding our own – something Aaronson thinks is simply absurd (for the debate, see Aaronson 2014a & 2014b). If we postulate that consciousness requires the activity Bohmian quantum information (or something analogous to it), such simple counterexamples will not work. In order for the system to be conscious, non-trivial quantum effects have to play a role in it.

A simple possibility would be to postulate that what makes a given mental state (or level of information or mental activity) conscious is that there exists a higher level of (typically) unconscious information, which has the content that one is in the first order mental state or activity (cf. Rosenthal 1997; Gennaro 2012). Note also that David Chalmers (1996) famously suggested that we tackle the hard problem of consciousness with a double-aspect theory of information. The idea is that information is a fundamental feature of the world, which always has both a phenomenal and a physical aspect. Now, we could take this idea to the Bohm scheme and postulate that active information, too, has phenomenal properties. This then raises the question about what we should think about the active information in the pilot wave of an electron. Does it, too, have phenomenal properties in some sense? We have seen that Bohm himself went as far as to say that an electron has a "primitive mind-like quality", but by "mind" he was here referring to the "activity of form", rather than conscious phenomenal experience in any full sense.

I think that it is reasonable to combine Chalmers's hypothesis with active information, but we need to restrict the hypothesis. For example, we could say that a certain kind of active information (for example, holistic active information that is analogous to quantum active information) has the potentiality for phenomenal properties, but this potentiality is actualized only in suitable circumstances (for example, when a given level of active information is the intentional target of a higher level of active information; or if we want to follow a Tononian-Baarsian approach, we could say that suitably integrated active information which can act as a global workspace is conscious). Of course, this also opens up the possibility for genuine artificial consciousness. If we could implement suitably integrated quantum-like active information in an artificial system and set up suitable higher-order relationships between levels and a global workspace in the system, phenomenal properties should actualize themselves, according to this type of hypothesis.

One advantage is that while Chalmers's double-aspect theory suffers from epiphenomenalism, Bohm's scheme, when modified, opens up the possibility of a genuine causal efficacy of phenomenal properties upon the physical domain (see Pylkkänen 2007: 244–6; Pylkkänen 2017). Also, Chalmers thinks it an interesting possibility that some sort of activity is required for experience, and that static information (e.g. information in a thermostat in a constant state) thus is not likely to have experience associated with it (1996: 298). If we say that phenomenal properties are always properties of some kind of Bohmian active information, we could do justice to the intuition that activity is required for experience.

11. Conclusion

We started off by noting that, given the *prima facie* absurdity of the notion that physical ultimates have mental or even experiential properties, those who find panpsychist arguments convincing may find themselves overcome by panphobia. We then examined in some detail Bohm and Hiley's proposal that elementary particles have mind-like qualities. Thus, panpsychism is not as anti-scientific as it may seem, and perhaps a cure or at least alleviation of panphobia is here available. However, there is one important point we need to consider. Bohm's idea that elementary particles (or physical ultimates) are not conscious (and that the quantum field of the universe as a whole is not conscious) means that one needs to appeal to some kind of emergence to account for consciousness; and emergentism and panpsychism are often seen as competing doctrines (Seager and Allen-Hermanson 2015: 3). Thus some panpsychists would not see the active information scheme – at least in the form I have presented it here – as a genuinely panpsychist one, but rather as a form of emergentism. If so, I suggest that the active information scheme makes emergentism a more plausible doctrine. It is easier to see how a mind-like state can become conscious, than how a "purely physical" state can become conscious. This intuition is shared by some higher-order theorists (see e.g. Lycan's 1996: 24) answer to the so-called problem of the rock for higher order theories). By postulating that mind-like qualities are a fundamental aspect of the universe, Bohm's active information and implicate order schemes make the emergence of conscious experience more intelligible.

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